Title: Review of the Digital Inject Book

Author(s):   Felsher, Paul D.
                Smith-Nelson, Mark A.

Intended for: Report

Review of the Digital Inject Book

Paul Felsher & Mark Smith-Nelson
Los Alamos National Laboratory
10/29/2012

Over the last year the Digital Inject Book (DIB) has been reviewed at LANL under the LANL10-RS-087J TI project. Several different versions of the DIB were used during the evaluation starting with version 9.8.7 and ending with 1.0.0.1824.

The DIB greatly simplifies some aspects of generating inject data and also enables one to rapidly make changes to the scenario and generate new data. The underlying code for generating gamma ray inject data is GADRAS, while the underlying code for generating most of the neutron inject data is SrcSim. Since GADRAS has been around for a significant period of time and has a relatively large user base, reviewing GADRAS itself was considered out of scope for this TI project. However, how the DIB utilizes and interfaces with GADRAS to generate the inject data was considered to be in scope. SrcSim on the other hand does not have the same kind of pedigree as GADRAS and has not been as widely evaluated. Therefore, this review will cover not only how the DIB interfaces with SrcSim, but also the SrcSim code itself.

This review is broken down into a number of individual topics and observations.

1D Gamma Transport in a 3D World

Although the DIB provides a visually appealing 3D environment for generating and viewing objects and scenarios, the radiation transport is still handled by GADRAS which is fundamentally a 1D radiation transport tool. The DIB uses a simple point to point (source-to-detector) ray trace to generate the simplified 1D pie diagrams that are fed to GADRAS. It is important that the user of the DIB recognize the limitations of using a process that automatically simplifies a 3D world into a 1D environment. (Note: the recently added RayTrace3D capability in GADRAS does not at all attempt to simulate the 3D environment that is missed by the simple 1D ray trace.) Several simple illustrations showing how a bad 1D approximation can adversely impact the simulated gamma ray spectra are shown below.

Gamma Ray Streaming
In this example, the BeRP ball and a cement block wall were selected from the pre-defined objects in the DIB (see figure 1). The BeRP ball was placed about 1 meter from the cement block wall and a DetectiveEX100 was placed immediately on the other side of the wall. Two inject simulations were performed where the only difference between them was that the second measurement point was translated horizontally less than 1cm (see blue and red arrows).
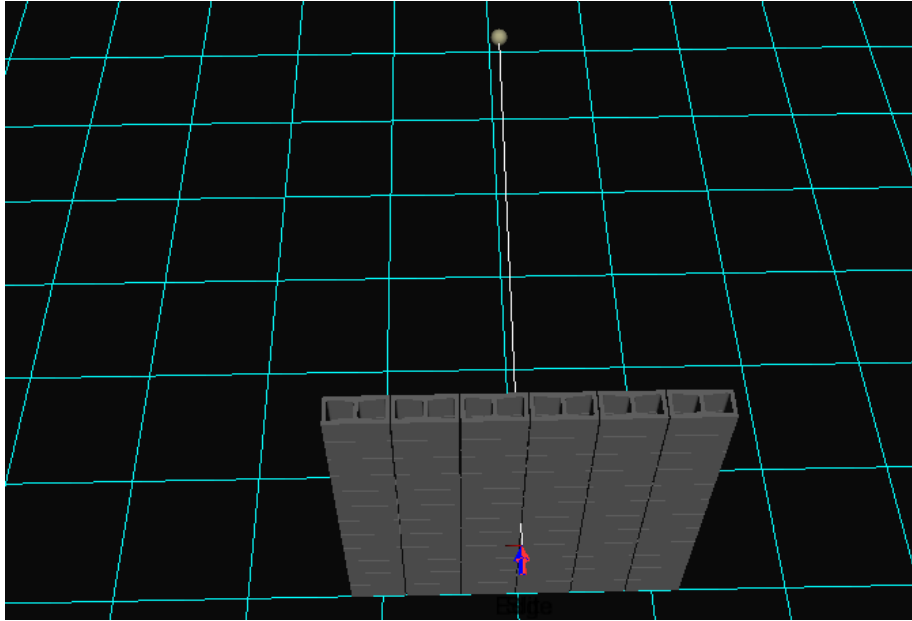
Figure 1

The computed gamma ray spectra for the two points exhibit significantly different characteristics (see figure 2). In the log plot below, the blue curve exhibits substantially more attenuation than the black curve. The overall gamma count rate for the blue curve is only 286 cps whereas for the black curve it is 2397 cps.
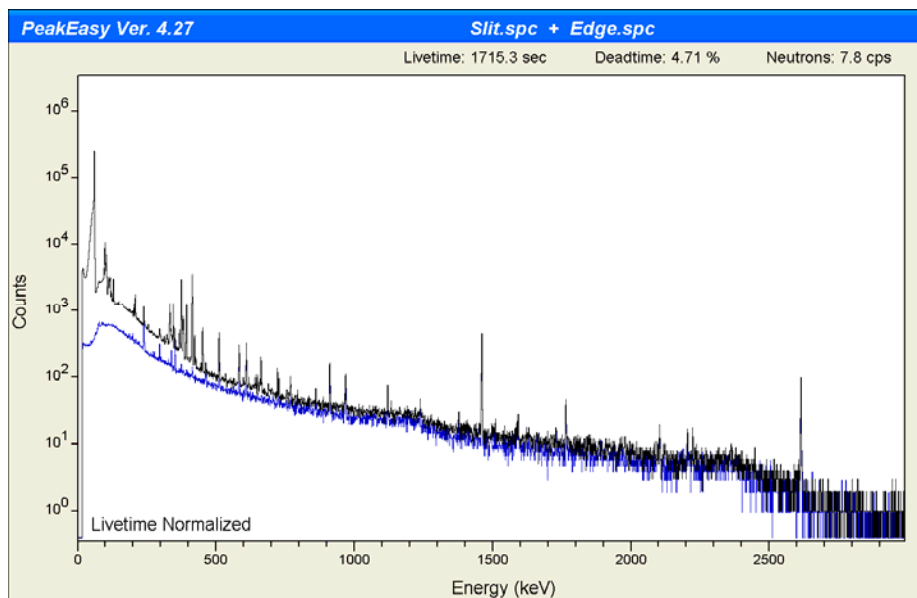

Figure 2

The most prominent peaks normally seen with Pu-239 are also very differently affected (see figure 3) in the two spectra. In the black curve they are clearly seen, but are severely attenuated in the blue curve and are barely evident.
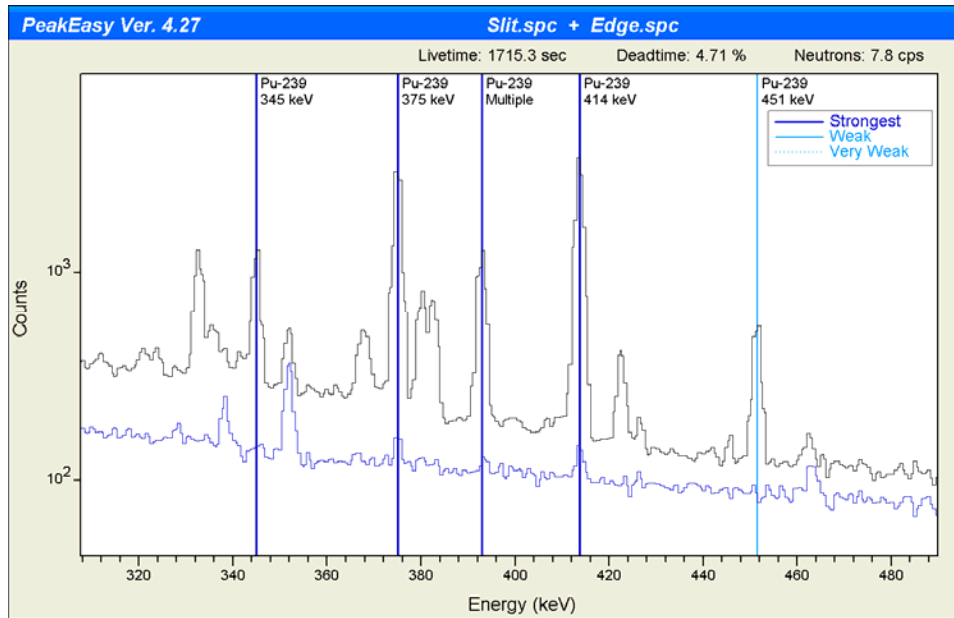
Figure 3

The conclusions and interpretations that a spectroscopist would reach using these two different simulations would be very different from each other. Neither of the spectra accurately represents what one would actually see in the real world. The very significant difference between these two simulations can be easily explained: one detector (blue curve) was lined up so the 1D ray trace went through approximately 20cm of concrete whereas the other detector (black curve) was lined up looking through the very thin crack between the cinder blocks. The gamma rays at the second location streamed right through the crack and thus did not experience any attenuation at all from the concrete. In reality, there should be little difference in the gamma ray spectra between these two points since both the source and the detector have finite dimensions, the crack was very thin, and not all gamma rays start and end at two single points and follow the exact same path between the points. The resulting spectra would thus show more of an average affect of the cinderblock wall and would be more of an average of the two spectra shown above.

Office Scenario – Unexpected Shielding

In the sample scenario distributed with the DIB, a number of objects are located in an office environment with an AmBe source located in the cardboard box on the other side of a concrete block wall (see figure 4). Locating a detector inject point just behind the office desk resulted in a 1D pie diagram with a staggering 60cm of plywood shielding the source (see figure 5). The only apparent wood (i.e., plywood) between the source and detector is the wood desk which should consist of relatively thin wood mostly of void space. That amount of plywood shielding would be inconsistent with this scenario. However, a thorough examination of the desk reveled that the desk drawer was modeled using solid wood (see figure 6). Unless the person generating the inject data was aware that the desk was modeled

with a solid desk drawer they could easily produce inject data that differed substantially from what was intended.
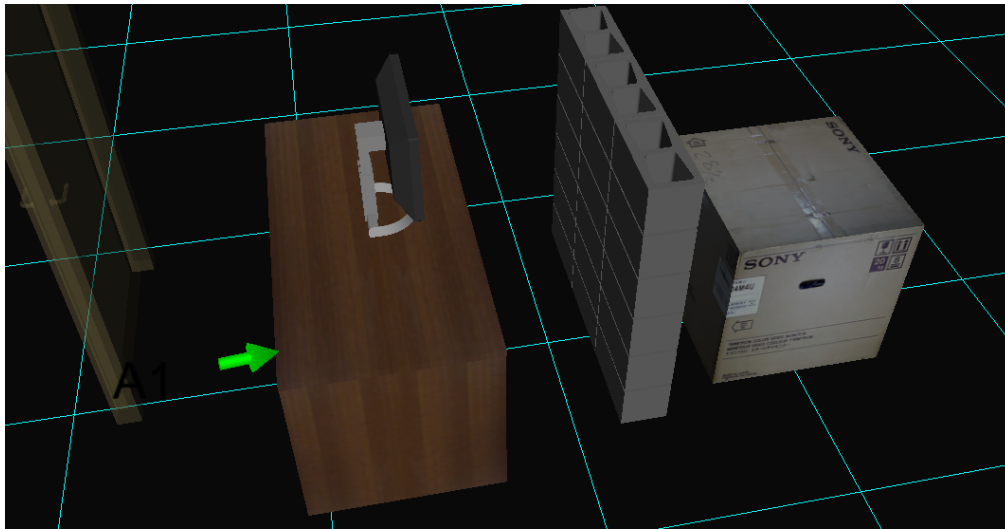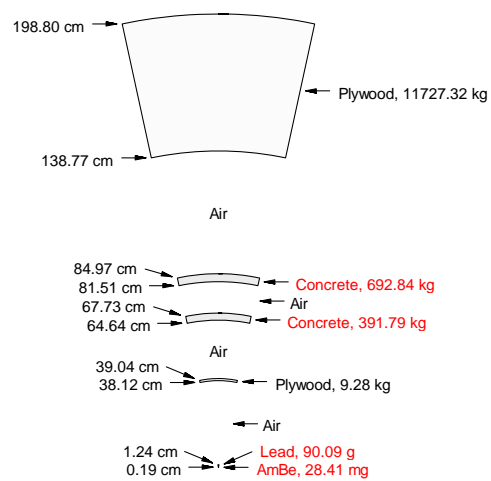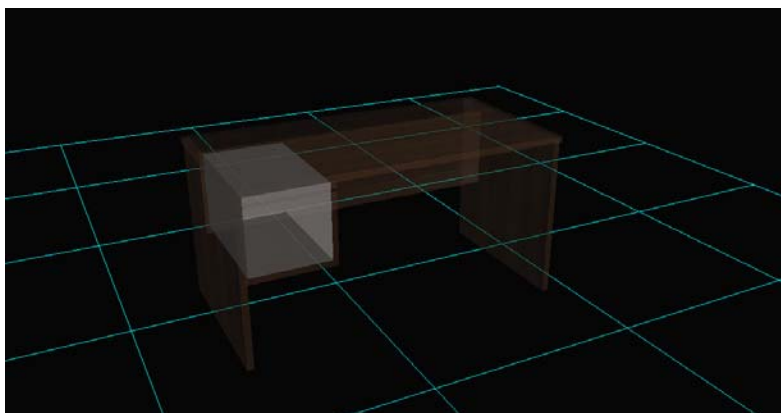

Figure 4

Figure 5

Figure 6

Shown in figure 7 is an example of another item that contains additional internal structure that is not immediately apparent when one simply selects pre-made objects from the object library. In this particular case, the pelican case contains an internal object consisting of an "electronic soup" which is as a homogeneous material intended to provide the same effective impact on the gamma rays as a collection of electronic components (circuit boards, wires, capacitors, etc.) would have. Knowledge of the presence of the electronic soup would be important for somebody using the pelican case in their model. Furthermore, a slight shift of the source, detector, or pelican case could cause the 1D ray trace to completely miss the soup or transverse it down its full length. Similar to that discussed above, the impact on the simulated inject could be traumatic and not at all intended.

Figure 7

Manila Folder – Sheet of Paper
In this example, a simple manila folder containing a few sheets of paper was placed between a 100uCi Ba-133 source (red arrow) and a DetectiveEX100 which was located 200cm from the source (see figure

8). The presence of a folder like this should have virtually no impact on the gamma ray spectrum due to its small dimension and low areal density. However, if by chance, the 1D ray trace went longitudinally down the length of the paper then the impact would be far from insignificant. In this simulation, two inject points were used (green arrows) – one which was directly in line with the paper in the folder and one which was slightly offset to the side of the folder. The gamma ray count rate for the inject point which was in line with the paper was 23% less than the unattenuated inject point. The reduction in the 303 keV peak areas was impacted even more and was reduced by 73% (see figure 9). These are huge numbers from a simple manila folder containing a few pieces of paper.
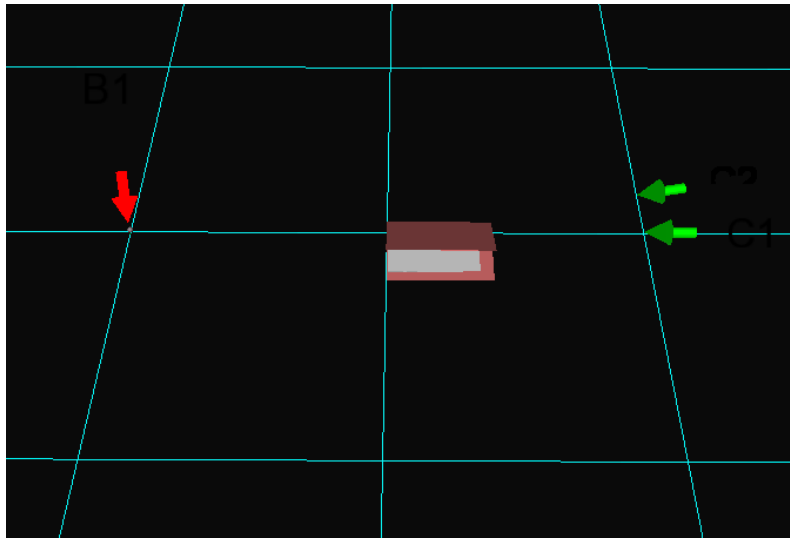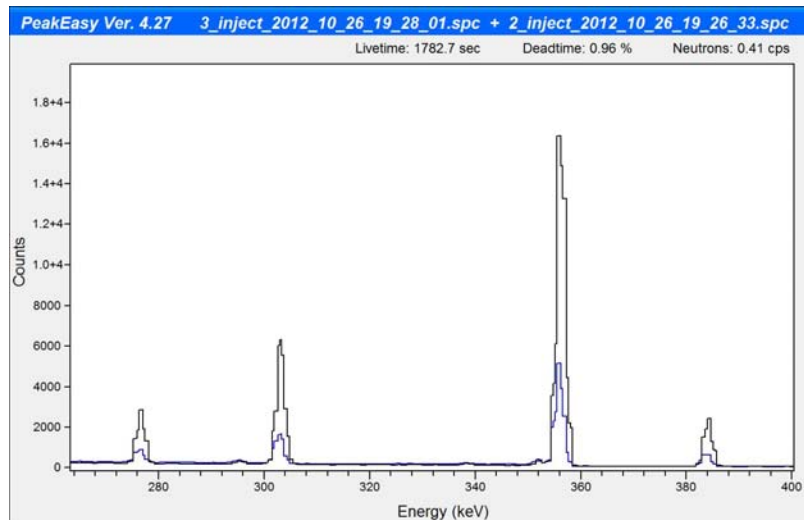

Figure 8

Figure 9

The examples above were intentionally generated to show how a seemingly minor change to a scenario could have very significant and undesirable consequences. High fidelity 3D objects make for very good pictures and images, but the more objects a scenario contains and the more detailed their construction,

the more likely one is to inadvertently run into a situation like those demonstrated above. Rather than a piece of paper causing the problem, one might accidently align the 1D ray trace along a 3-inch steel bolt, a thick flange, the axel of an ice cream cart, or the air gap between two 55 gallon drums of water. In general, the more detail one puts into a 3D object the more care one needs to exercise when one uses an automated tool to simplify the 3D object down to a 1D line containing a homogenous material. It is vitally important that the user of the DIB examines the pie diagrams for each simulation to ensure they don't suffer from the type of situation discussed above.

More User Control of GADRAS Inputs

As experienced GADRAS users, we would like to have more direct control over some of the inputs passed on to GADRAS (see figure 10).
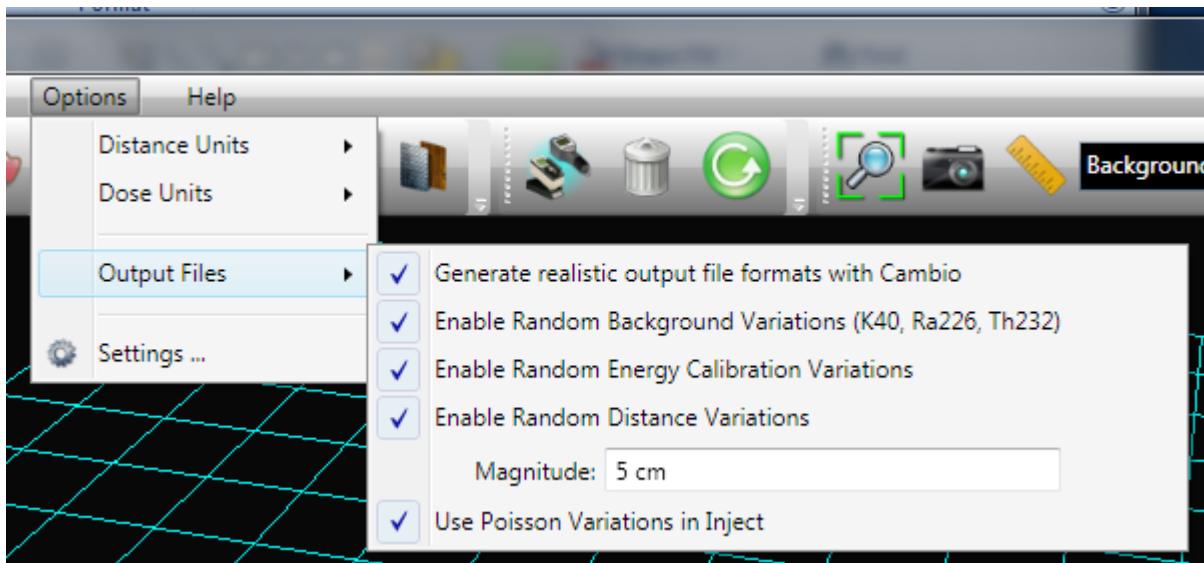
Figure 10

For example, rather than randomly varying the background, we want to be able to set the background to match the situation. Furthermore, if we need to add an additional simulation in the future we want to be able to use the same background previously used. Direct access to the background parameters available in GADRAS would enable the user to more appropriately control these parameters.

Variations in energy calibration can be quite situation dependent. Some detectors are very stable and drift very little, while other detectors are highly sensitive to their environment. The detectors also don't tend to drift rapidly (unless exposed to sudden temperature changes). Therefore, most measurements performed at the same time using the same detector should have similar calibration parameters. For some training exercises it may be desirable to have widely varying calibrations between sets of measurements. Direct access to the detector calibration parameters available in GADRAS would enable the user to more appropriately control these parameters.

Distance measurement errors are usually greatest during the early stages of an event when less experienced users are operating the equipment and when less is known about exactly where the source is located. As the event unfolds the variations and measurement errors tend to decrease. Being able to directly control the distance variations by setting the detector at a specified location, but reporting something slightly different in the inject book (i.e., the data used by the controller to give to the players) would be desirable.

Comparison of Neutron Experimental Data to Inject Data

An attempt was made to model previously measured configurations with the nPod and Fission Meter by using the DIB. The first attempt was to model the Thor Core (~8 kg of delta phase plutonium) with a Cf-252 source placed in the glory hole. This configuration requires the use of two neutron starters, which are the Pu-240 present in the Thor Core and a Cf-252 source. We were not able to make this model because the DIB only allows for one source of starter neutrons. The DIB should be able to accommodate at least two sources of starter neutrons.

Case Study

Modeling of Rocky Flat Shells (1-22) surrounded by high density polyethylene.

The second model attempted were the bare Rocky Flat shells one through twenty-two (1 to 22) surrounded by 2 inches of high density polyethylene moderator for the nPod and Rocky Flat shells one through twenty-four (1 to 24) for the Fission Meter. Unfortunately, data for both the nPod and Fission Meter were unavailable for identical experimental conditions. When making the model in the DIB (using the *Design Layered Solid* dialog box) we were only able to modify the thickness of the HEU and not the density or the mass. It would be useful to also include the ability to modify the mass and the density of the object. For example, in this case with the Rocky Flat shells, they are a series of nesting HEU shells that when assembled, the conglomerate density (18.0 g/cc) is slightly less than the solid metal HEU density of 18.9 g/cc because of the gaps between the nesting shells.

When creating this model the Fission Meter and nPod were placed at a cursor location and then the model was saved. At this point the data was updated and SrcSim was run in the background. Unfortunately not all of the parameters were entered into the SrcSim override dialog box and when SrcSim ran it took an extremely long time to run, over ten minutes. This would not be a problem if hitting the cancel button on the *Updating Data* progress box would immediately terminate the SrcSim application. SrcSim had to be terminated manually through closing the command line box. The parameter that was not entered correctly in the SrcSim Override dialog box was efficiency, it was set to zero. There should be a check on the input parameters to insure that the efficiency is between 0.0 (not inclusive) and 1.0 (inclusive).

The parameter "FM NumCycles" default is 1000000. This is a non-descript number and there should be some indication of count-time in the SrcSim Interface for both the nPod and the Fission Meter. The default number of segments for the nPod is 50 segments. This parameter should be based off of count time and not total number of segments. For this example, with ~83,000 counts per segment in the nPod, the total run time for a segment is 83,000 seconds, or 23 hours.

The configurations with the Rocky Flat shells are 11.4 kg of HEU (shells 1 – 22) and 13.7 kg (shells 1-24) with no driver in the middle and total multiplication of approximately 5.2 (shells 1-22) and 6.5 (shells 1-24). The nPod was placed 13.25 cm from the configuration and the Fission Meter modeled in the open position at 30 cm from the HEU. The nPod estimated efficiency in this configuration is about 2 percent and the estimated Fission Meter efficiency is 1.6 percent.

In order to calculate the inject data for the nPod and the Fission Meter, the SrcSim Input Override needs to be executed. The source description doesn't change, e.g. Source Type, Source Strength, and Multiplier Type. The detector responses, such as the efficiency and the Neutron Lifetime, do change. These two parameters need to be associated with the detector and should not be global parameters that need to be changed for each run of the data.

When the inject date was created a *.DAT and a -2A file are created. The filenames for the inject data should reflect a real filename. For example, with the nPod the filenames should be of the form YYMMDDRR.DAT where YY is the two digit year, MM is the two digit month, DD is the two day digit day, and RR is the two digit run number. For the Fission Meter, the filename form should be DDMMYYYY_hhmmss-2A.log, where DD is the two digit day number, MM is the two digit month number, YYYY is the four digit year number, hh is the two digit hour number, mm is the two digit minute number and ss is the two digit second number of when the file was recorded. Also, when one looks at the comments in the -2A.log file that is created, all of the input parameters are there, such as total multiplication, efficiency, source strength, source type, source multiplier, etc. These parameters do not belong in the -2A.log files and should be removed.

Comparison of the nPod inject data to measured data

The *.DAT file was analyzed to examine how well the data reflects actual measured data. The point here is that inject data should be indistinguishable from measured data. A comparison (see figures 11 and 12) of the Y2 plots for the nPod show good agreement in the shape, but the magnitude of the count rates is inconsistent. For example, the count-rates given by the DIB are about five times higher than what was measured for the same configuration. However, the uncertainty in the doubles, triples, and quad rates is consistent in magnitude (i.e., the amount of scatter for the doubles rate is 0.026 for measured data and 0.020 for the simulated data).
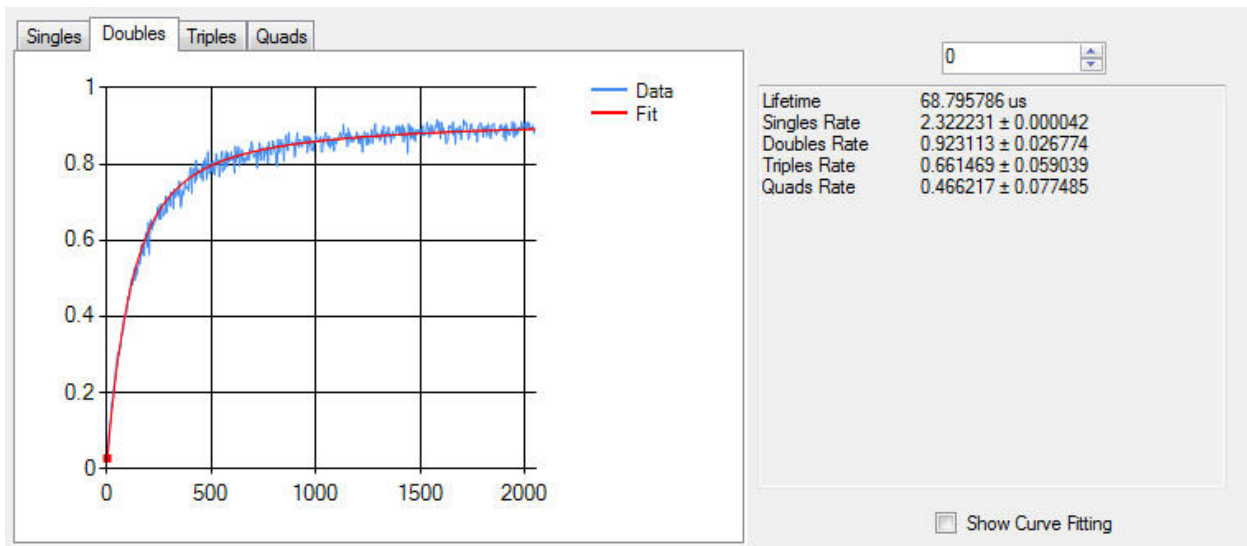
Figure 11. Y2 plot of data taken with nPod for rocky shells 1-22 surrounded by 2" of HDPE
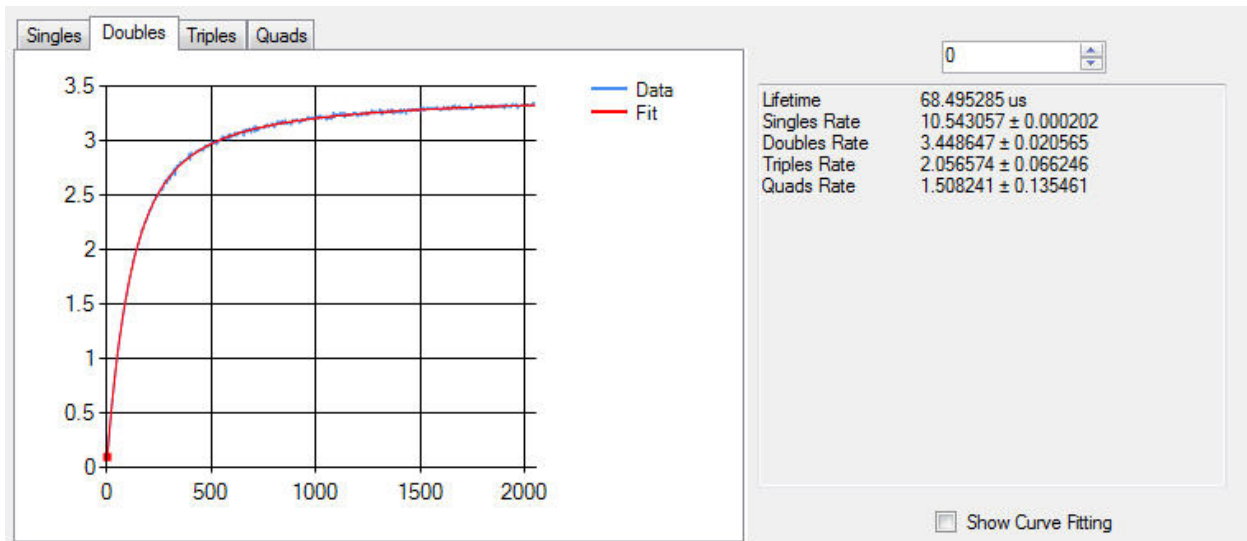

Figure 12. Y2 plot of data created with DIB of the rocky shells 1-22 surrounded by 2" of HPDE.

Comparison Fission Meter inject data to measured data

The data rates created by SrcSim were on the high side for the Fission Meter by almost a factor of two. A way to estimate the efficiency of the Fission Meter was not available in the DIB and so the efficiency was calculated from previously measured data. One can see the uncertainties in the data created by the DIB are significantly higher than what is seen in the measured data. This can be seen in the different amounts of scatter in the data in figures 13 and 14. This difference in the amount of scatter is most likely due to a different binning scheme used for the Feynman Histograms in SrcSim than what the Fission Meter actually uses.

The simulation was rerun and put into a *.DAT file and then resampled using the binning structure used in the Fission Meter. The resulting Y2 plot is plotted in figure 15 and shows that the amount of scatter is much closer to the measured data in Figure 14.
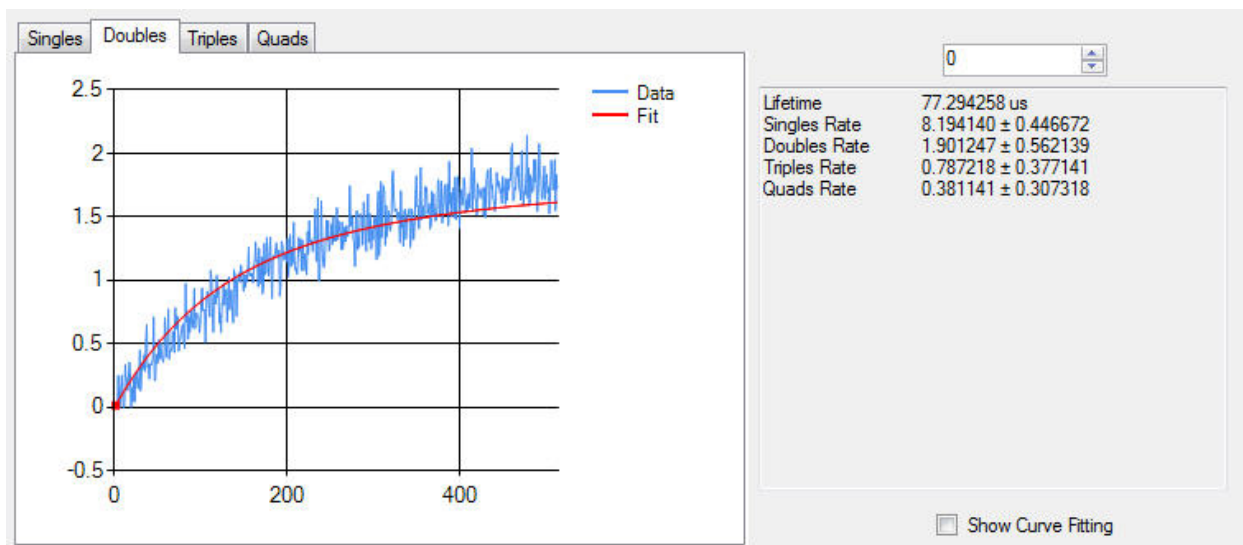

Figure 13. Doubles rate from the DIB for the Fission Meter for Rocky Flat shells 1-24.
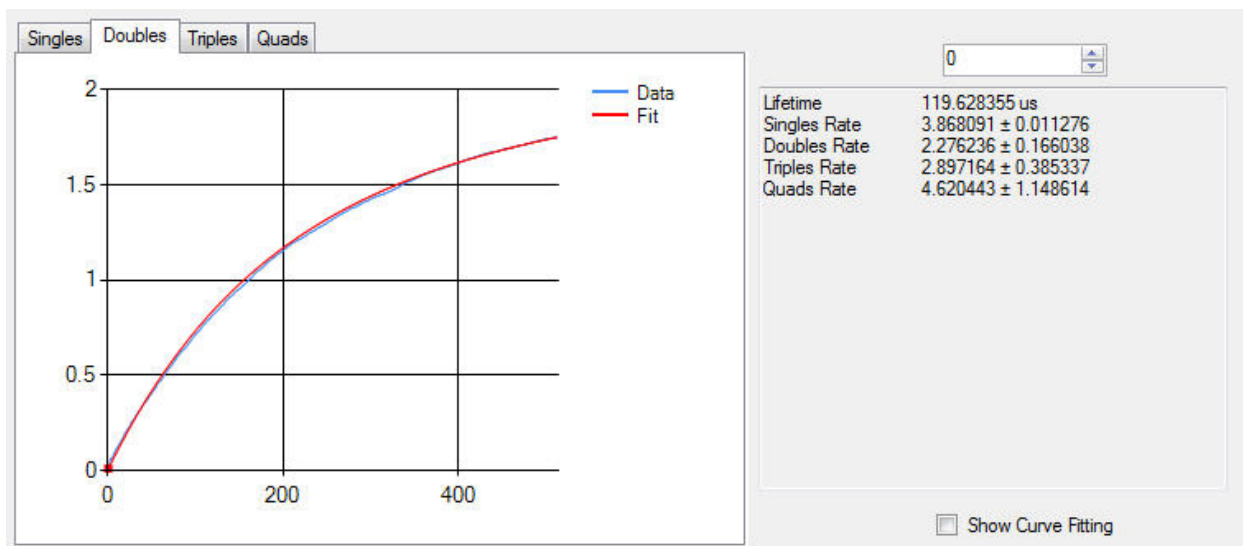

Figure 14. Doubles rate for measured data for the Fission Meter for Rocky Flat Shells 1-24.
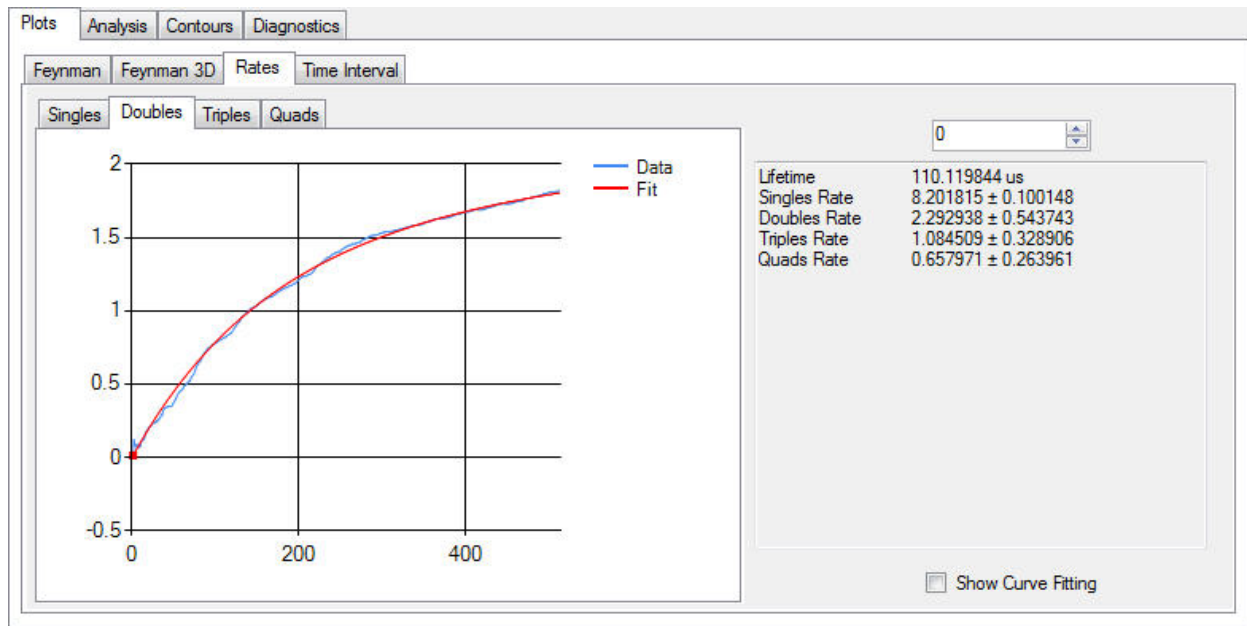
Figure 15. The resampled *.DAT file for the Fission Meter for Rocky Shells 1-24.

XXXXXXXXXXXXX General Comments on the Digital Inject Book

1) The nPod Detector Definition has a default deadtime of 20 us. This deadtime should be 4 us.
2) The SNAP (both bare & poly) have a default deadtime of 20 us. Again, this deadtime should be 4 us.
3) The Fission Meter default deadtimes (both for open and closed) are set at 20 us. These deadtimes should be 3 us.
4) The default output file for the SNAP (both bare & poly) is a "Gr135Dat." The output from the SNAP should be written down in a text file because there is no default electronic file. The data from the SNAP is written down & then transcribed to an electronic file.
5) When the nPod is inserted the error comes up indicating that the profile is not complete. The profiles listed are for 0.5, 1.0, 1.5, 3.0, & 6.0 inches of undetermined material. I assume this is high density polyethylene. I assume this is for determining the row ratios. However the row ratios are different for different types of moderators.
6) When placing a detector only the X, Y, & Z coordinates are shown. There should be a distance calculation in here as well. Additionally, the distance should be adjustable along the current unit vector described by X, Y, & Z. i.e. when the distance parameter is set the detector should move along the unit vector described by X, Y, & Z to the defined distance.
7) The data created for the SNAP is a GR-135 data file & has a spectrum associated with it. The SNAP doesn't collect any gamma data, let alone a spectrum.

8) It is unclear if the bottom plane is a solid or just a reference point when performing neutron simulations.
9) A simple bare BeRP ball model was created with the SNAP at 100 cm away and 100 cm up from the floor. The SNAPBare NSS was 954,070. This is in agreement with measurements. However, the SNAPPoly NSS is 448,701. This is not in agreement with measurements, which the NSS should be around 780,000. Reference data used was from Mattingly's Jan 2009 measurements.
10) The default neutron lifetime for the nPod is 50 us when "SrcSim Input Override" was selected. This value should be 40 us.
11) The only way to get nPod & Fission Meter data is select "SrcSim Input Override." In this override both "Override Source" and "Override PointKinetics" must be selected. Both of these overrides need to have other calculations done before they can be inputed. E.g. The "1D Model Layers" only displays thickness & Material. The information needed to calculate the source strength is not present (i.e. how much Pu is present in the BeRP ball?). In the "Override PointKinetics" section it requests Multiplication, Efficiency, and Neutron Lifetime. This information is not present.
12) The efficiency for the SNAP is inconsistent with actual values reported by the SNAP. Especially since the DIB efficiency increases as the SNAP gets closer to the floor. This is opposite of what is expected.

S-D	R-D	Eff reported by DIB	Eff reported by SNAP
100 cm	30 cm	0.0066%	0.0074%
100 cm	60 cm	0.0074%	0.0065%
100 cm	100 cm	0.0074%	0.0059%

13)

14) For high count rates in the nPod & Fission Meter, there is no evidence of deadtime effects even though there is a space for entering deadtime in Analysis→Manage Gadras Detectors… → NPOD, FissionMeterOpen, or FissionMeterClosed.
15) There don't seem to be any room return effects in the neutron data. i.e. the nPod data is the same regardless of how high the nPod is above a concrete floor.

General Comments

- Only an experienced GADRAS user and spectroscopist should use the DIB to generate inject data for a high profile drill (JD, BiLat, Marble Challenge, etc.). There are too many ways to easily generate bad or inconsistent data. Running the internal QA Check (DHS Isotope ID) may help catch some of the most obvious errors, but it is not a sufficient test to ensure the simulated data is correct. Furthermore, while the tool allows one to easily generate inject on the fly during an exercise the likelihood of generating poor quality data increases as the exercise controller becomes more fatigued and is subjected to greater time pressures.
- We were unable to install the DIB on a Windows XP machine.

- A thorough review of how the DIB handles multiple sources would require reviewing the mathematical details of how the GAM files are added, when background is or is not included, when and how Poissonian variations are generated, and how radiation transport through radioactive layers is handled. Without knowing these details, it is only possible to spot check how multiple sources are handled.
- Gamma and neutron count rates in the report.pdf file appear to be based on the interim pcf file and not the spectral file that is ultimately produced for inject. See for example a pcf file and its associated spc file for a DetectiveEX100.
- Add an option to clone detectors similar to the feature currently in GADRAS.
- Decrease the level of visual fidelity in the various models and objects and simplify them by including more "electronic soup" type material mixtures. This will help eliminate some of the issues of inadvertently aligning the 1D ray trace along a piece of paper, bolt, etc.
- Create a user warning when 1D ray traces vary significantly over small transverse translations. This possibly could be implemented by generating multiple ray traces starting near each source point and terminating near the inject point and performing some comparison between them.
- All SPC generated spectra files from the DIB contain: "Reported in File: Found: NORM background OK, Cs137, Co60, K40, Neutron source present   Suspect: NORM background OK, Ra226, Neutron source present." This message is supposed to come from the detector's internal isotope ID algorithm and may be appropriate for a particular situation, but it certainly is not accurate or appropriate to include in every SPC file.
- Pre-made source objects have their reference point at their origin rather than on the periphery. (See for example the predefined BeRPBall. When it is placed at (0,0,0) its center is actually located at about (0,0,8). Recommend creating pre-defined spherically symmetric source objects so that their reference point is located at the center of the object.
- Suppressing the radioactivity of a shell should only be exercised by an experienced GADRAS user. Having this option so readily available to the user might not be a good idea.
- Create more video help files. The existing ones were quite useful for the inexperienced DIB user.
- Create a more extensive help document including indexed searching.
- When typing in distances or dimensions it would be nice to be able to enter the number and the units and have the DIB automatically convert it into cm. (Enter 1i and have DIB automatically convert it to 2.54cm.)
- Enable the DIB to utilize a full 3D computational code (e.g., MCNPX). Of course, the required computational times will increase substantially compared to a 1D code like GADRAS.
- The nPod Detector Definition has a default deadtime of 20 us. This deadtime should be 4 us.
- The SNAP (both bare & poly) have a default deadtime of 20 us. Again, this deadtime should be 4 us.
- The Fission Meter default deadtimes (both for open and closed) are set at 20 us. These deadtimes should be 3 us.

- The default output file for the SNAP (both bare & poly) is a "Gr135Dat." The output from the SNAP should be written down in a text file because there is no default electronic file. The data from the SNAP is written down & then transcribed to an electronic file.
- The data created for the SNAP is a GR-135 data file and has a spectrum associated with it. The SNAP doesn't collect any gamma data, let alone a spectrum. Generating a spectral file when one shouldn't exist is inviting problems.
- When the nPod is inserted into a scenario an error comes up indicating that the profile is not complete. The profiles listed are for 0.5, 1.0, 1.5, 3.0, & 6.0 inches of undetermined material. We assume this is high density polyethylene and is used for determining the row ratios. However, row ratios are different for different types of moderators.
- When placing a detector, only the X, Y, & Z coordinates are shown. There should be a distance calculation in here as well. Additionally, the distance should be adjustable along the current unit vector described by X, Y, & Z. i.e. when the distance parameter is set the detector should move along the unit vector described by X, Y, & Z to the defined distance.
- For neutron simulations, it is unclear if the bottom plane in the scenario viewing window is a solid surface or just a reference point.
- A simple bare BeRP ball model was created with the SNAP at 100 cm away and 100 cm up from the floor. The SNAPBare NSS was 954,070. This is in agreement with actual measurements. However, the SNAPPoly NSS is 448,701. This is not in agreement with actual measurements, which have a NSS around 780,000. Reference data used was from Mattingly's Jan 2009 measurements.
- The default neutron lifetime for the nPod is 50 us when "SrcSim Input Override" was selected. This value should be 40 us.
- The only way to get nPod & Fission Meter data is to select "SrcSim Input Override." In this override both "Override Source" and "Override PointKinetics" must be selected. Both of these overrides need to have other calculations done before they can be inputed. For example, the "1D Model Layers" only displays thickness & Material. The information needed to calculate the source strength is not present (i.e., how much Pu is present in the BeRP ball?). In the "Override PointKinetics" section it requests Multiplication, Efficiency, and Neutron Lifetime. This information is not present.
- The efficiency for the SNAP is inconsistent with actual values reported by the SNAP. Especially since the DIB efficiency increases as the SNAP gets closer to the floor. This is opposite of what is expected.

S-D	R-D	Eff reported by DIB	Eff reported by SNAP
100 cm	30 cm	0.0066%	0.0074%
100 cm	60 cm	0.0074%	0.0065%
100 cm	100 cm	0.0074%	0.0059%

- For high count rates in the nPod & Fission Meter, there is no evidence of deadtime effects even though there is a space for entering deadtime in Analysis→Manage Gadras Detectors…→ NPOD, FissionMeterOpen, or FissionMeterClosed.

- There doesn't seem to be any room return effects in the neutron data (i.e., the nPod data is the same regardless of how high the nPod is above a concrete floor).